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Quarterly Technical Summary

Educational Technology Program

15 December 1970

Prepared under Electronic Systems Division Contract F19628-70-C-0230 by

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts

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ABSTRACT

Work this quarter has concentrated on planning for the Keesler trial of the LTS and the design of appropriate facilities to support that effort. Considerable progress has been made in the hardware development program. In particular, techniques have been developed for storing, on microfiche, sampled audio signals as two-level diffraction gratings. Construction of the LTS-2 breadboard system has begun.

15 December 1970

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Accepted for the Air Force
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EDUCATIONAL TECHNOLOGY PROGRAM

I. EDUCATIONAL DEVELOPMENT PROGRAM FOR THE LTS

A program of research and development using the LTS terminal has moved forward in several respects during the quarter.

One purpose of this activity is to begin a field trial of the terminal in a typical training environment. Toward this end an arrangement has been made with the Air Training Command to install and operate a trial class unit at the Keesler Technical Training Center. The purpose of this trial is to prove that a console that functions like LTS-1 can serve as the main teaching medium in a self-paced training environment.

A second area of concern is the study and refinement of new educational methods in this environment, and both formal and informal experiments are in progress. The initial goal is mainly to acquaint ourselves with the nature of learning performance in a variety of situations.

A. The Keesler Trial

It has been shown repeatedly that machines can be used successfully for many forms of instruction. It has also been shown that when each trainee is permitted to work at his own pace, very substantial savings in training time are achieved. The LTS is designed to provide machine support for this type of individualized technical training. The major goal of the Keesler trial is to demonstrate that with such support it will be possible to extend greatly the amount of individually paced training in the present Keesler environment.

Use of the LTS has at least two unique advantages over use of conventional materials for programmed instruction: (1) audio presentation and (2) automatic student monitoring. An audio channel permits verbal instruction for those who, for whatever reason, listen better than they read. In the class with self-paced instruction, the instructor faces the problem of keeping track of the progress and problems of many trainees, each at a somewhat different stage of the course. This is a very real problem and some form of computer managed instruction (CMI) is required. The use of a machine like the LTS makes real-time CMI economical and easy to achieve.

A specific plan has evolved for a joint venture with the Keesler Technical Training Center. Two weeks of the fundamentals of electronics course and two weeks of the air traffic controller course have been selected as material. Four consoles, based on the LTS concept, and a small computer will be provided to serve six to eight students. About half of the actual training time will be on the machine, the remainder on the bench and elsewhere.

Each lesson frame will contain four elements: audio, visual, control, and "lesson code." The control information provides for branching – the next frame is selected according to the student's response choice. The "lesson code" is a machine-readable tag specified by the author of the course. This may be used effectively in a programmed instruction environment where, for example, each frame is coded to indicate which of the behavioral objectives of the course are served by that frame. Thus the monitoring computer can accumulate a record of errors and total time separately for each behavioral objective. Even a small computer can carry out this function for a whole classroom of terminals. Such a report, provided at the end of each lesson, informs the student and instructor on progress – especially when compared to norms established

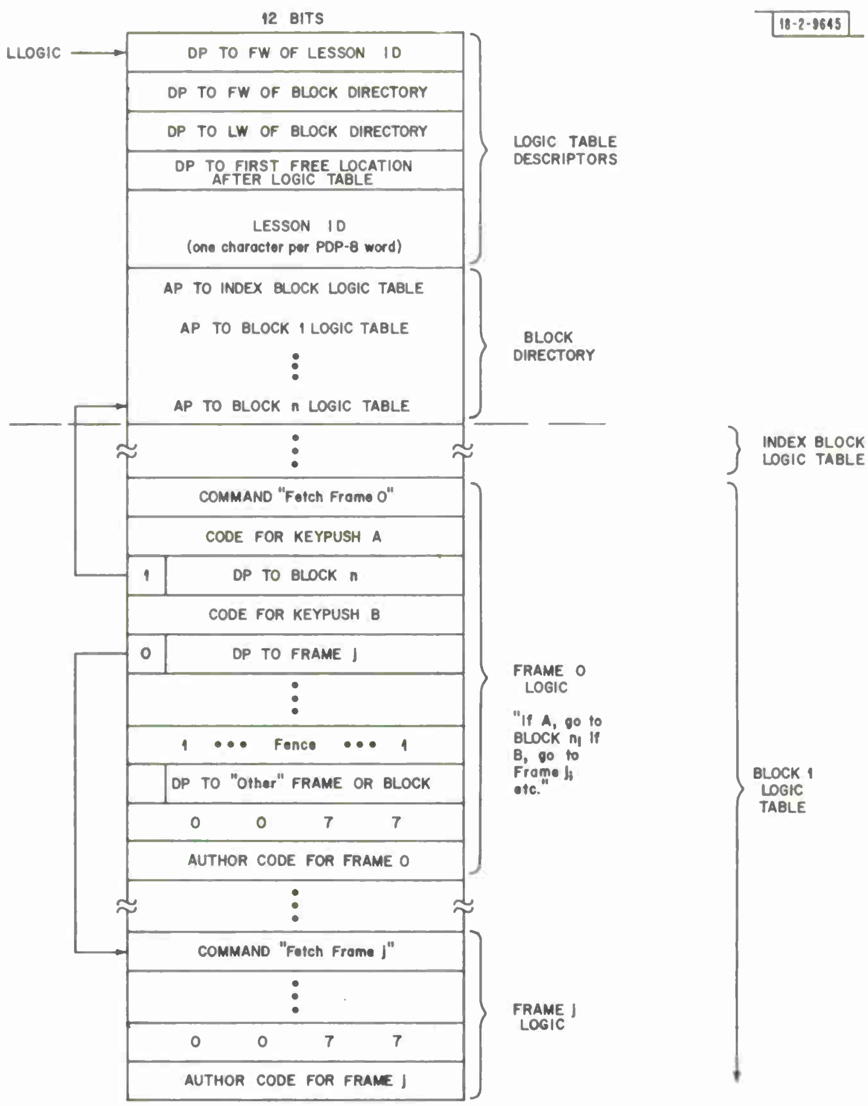


Fig. 1. PDP-8 format.

for prior classes of trainees on the same material. It is planned for Keesler personnel to prepare materials and specifications, adapting the Keesler educational philosophy to this new environment. The Laboratory will provide the terminals, computer, computer software, course material preparation facilities, and both hardware and software support services.

B. Preparation of Lesson Materials

In putting together a course for the LTS-1, the author has to construct his course logic, which must then be converted to paper tape for use by the PDP-8. A program is being written on the IBM 360/67 that will interactively aid the author in doing this.

The format needed for the PDP-8 is shown in Fig. 1 (DP means relative addresses; AP, absolute ones). A Fortran program will convert a typed file, such as shown in Fig. 2, into the correct format, which will then be punched out on the high speed paper tape punch on the IBM 67.

-2-9623

```
S     BLOCK 10
S         FRAME 126        BIN 126
S              ON YES    GOTO 19
S              ON NO     GOTO 150
S         FRAME 19         BIN 19
S              ON GO-ON  GOTO 150
S         FRAME 150        BIN 150
S              ON GO-ON  GOTO 25
S         FRAME 25         BIN 25
S              ON A      GOTO BLOCK 12
S              ON B      GOTO BLOCK 13
S              ON C      GOTO 150
S
```

Fig. 2. Author's file.

The program will correct errors that are obvious to it as the author writes them. For instance, if the author adds within one block a reference to a frame outside that block, the program will prompt him for corrections.

Accompanying the program will be a manual that should enable an author to construct a course with very little outside help. A first draft of the manual has been written.

C. Educational Research

Efforts to uncover some of the teaching characteristics of LTS currently center in two areas.

A short course teaching one technique of mental arithmetic is being put together for the LTS-1. The name of the course is "How to Multiply in Your Head," and it will consist of about 150 sound-slides, with course logic, and a manual available to the student. First tests on the course should begin by December 1970.

The topic was chosen because it is frankly academic, and found hard by most people. It was felt that if it were successful it would prove the usefulness of the LTS-1 and its philosophy in an unimpeachable way. It will also be a useful vehicle for improving other parts of the system. It is not clear that the course will have any other broad application, but it is directed at least at a part of the educational system in public schools that has been a widespread failure in general.

The course is organized in a straightforward way. Each block is either a demonstration, quiz, explanation, protocol, or correction block. It is hoped that the course will allow for differences in speed of comprehension of at least a factor of ten.

Work continues on a formal experiment, using a programmed lesson on meat carving, a subject that does not require trainees to have specialized backgrounds. The lesson is adapted

from a conventional text with numerous step-by-step photographs, each accompanied by a brief paragraph of instructions. Student performance will be tested in relation to instructions communicated either by audio or video messages. Whether a student listens or reads should change the student-lesson interaction in significant ways which instructors might consider when they develop lesson materials. The experimental plan departs from the conventional group comparison design. Instead, each student will be his own control. Two forms of the lesson have been prepared, each consisting of six topic units with audio instructions and six with video. Units that are audio in one lesson are video in the other. A student will initially learn the material from the lesson in one form and, after a delay during which he is likely to forget some portion of it, relearn it in the other form. The usual pre- and post-tests will be administered. Other results suggest that learning will occur, but little difference between treatments is to be expected. However, it is hoped that comparison of performance of audio/video within lessons and between learning and relearning should reveal details of the learning process as a function of presentation mode at the level of the individual subject.

D. Redesign of LTS-1 Console Program

Modifications of the PDP-8/I control program for LTS-1 have been completed. Small improvements have been made in the hardware, as a result of life tests conducted on the apparatus, and the hardware and software appear to be ready to support fully the research program outlined above and course preparation for the Keesler trial.

II. LTS-2 DEVELOPMENT

During this quarter we developed techniques for storing sampled audio signals, such as two-level (black-white) diffraction gratings, on microfiche, and have started to construct the first breadboard audio read system. Our effort to develop high-resolution multilevel diffraction recordings continues and is expected to yield higher recording density than is presently possible with two-level records. The design of the self-contained logical processor has been completed, and construction of this subsystem has begun. A two-axis random-access film platen was built and tested, and it satisfies the requirements for accuracy and access time. This subsystem will, however, be modified to improve reliability and to reduce construction costs.

A. Random-Access Film Transport and Projection Optics

A breadboard x-y table provides for the selection of the appropriate video and audio frame from a 192-frame (12×16) microfiche card. Access time for the extremes of travel in both axes simultaneously was demonstrated to be less than one second. The registration of the test frames was measured using a microscope and found to be less than 25 μm. Some features of the breadboard model are being redesigned to simplify the construction and increase the stiffness of the x-y transport mechanism.

A tentative console design has been made to facilitate the study of how the various components can be assembled into a system. Components affecting the console design are: the size and location of the x-y table, requirements of the optical path for the video image, requirements of the video illumination system, and the size and locations of the audio reading components. The method of loading the microfiche cards and the ease of maintenance of the x-y table and associated components are also considerations affecting the design of the console.

B. Audio Recording Techniques

Currently the speech waveform is being sampled and digitized prior to coding onto the film storage medium. A sketch depicting the initial coding scheme is shown in Fig. 3. Each bit is represented by a pair of spatial sinusoids; one sinusoid being present for a one, the other being present for a zero. Five bit-pairs represent one speech sample. Initially two 10×10 orthogonal output arrays will be used, with eight columns used for data and the rest for tracking and control information. This yields an initial storage density of 16 speech samples per patch.

Data are stored in the form of a sampled-binary-Fourier-transform hologram. For each patch the ideal amplitude-transmission function is computed at (75×75) points. Only the points at which the desired amplitude-transmission function is positive are recorded on the computer output microfilm with totally black dots. The microfilm is then photoreduced onto a high-resolution photographic plate to attain the desired patch size. The result is a photographic plate with a pattern of fully exposed points as shown in Fig. 3(a). A typical diffraction pattern is shown schematically in Fig. 3(b), and photographically in Fig. 3(c).

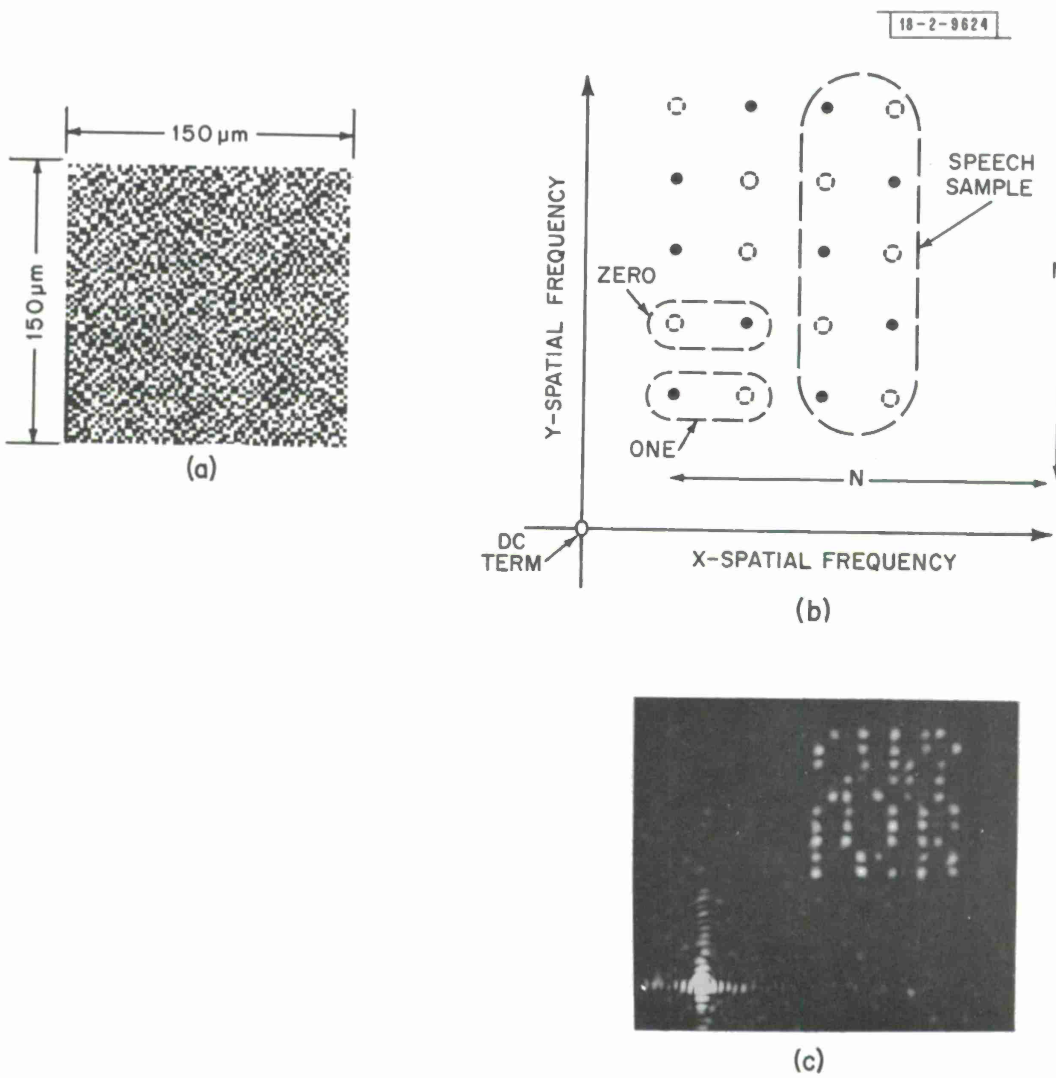


Fig. 3. Initial coding scheme: (a) diffraction patch; (b) diffraction pattern schematic; (c) diffraction pattern.

The sampled-binary-Fourier-transform hologram has a number of advantages over continuous-gray-scale holograms. First, the sampled binary hologram is ideally suited to computer output microfilm (COM), a readily available piece of equipment. Second, the binary recording is compatible with high-resolution film, which is basically high-contrast. In addition, binary recording is insensitive to film nonlinearity. Another advantage, since the film is either transparent or opaque, is that noise due to film granularity is, in theory, small. Finally, less control is needed for exposure and development, thus making binary holograms suitable for mass reproduction. A disadvantage of the binary-Fourier-transform hologram is its limited dynamic range, because of intermodulation distortion due to the hard-limiting of the sum of spatial sinusoids. For a binary coding scheme, the signal-to-noise ratio is high enough (+12 dB) and yields an error probability ($P_e \leqslant 10^{-4}$) which is sufficiently low for high-quality speech. Signal-processing techniques are currently being investigated to reduce the intermodulation distortion.

A patch, coding 16 data samples of five bits each, is produced using the SC4060 microfilm plotter. As produced it occupies a square 3.75 mm on a side. The microfilm plotter is capable of producing an array of patches about five deep, and as many across as desired. A microfiche frame of 50 × 50 patches can, therefore, be assembled from 10 microfilm strips, each containing a 5 × 50 array of patches, using a step-and-repeat camera. The computation associated with producing each patch is primarily a 75 × 75-point two-dimensional discrete Fourier transform. This computation is currently done on the Laboratory's IBM 360 computer system. We are preparing a program for the Group 64 Fast Digital Processor, which will result in the computation of discrete Fourier transforms almost two orders of magnitude faster than presently possible with the more conventional computer facility. We are also considering the development of a special-purpose computer program to reduce the plotting time necessary to make a microfilm patch.

To date, we have put arrays of patches on microfilm, reduced the patches to final size on glass plates, and successfully read the data by eye, using a laser.

C. Audio-Read-System Development

A breadboard system, having the essential features of a later prototype system (except for the x-y film platen), is under development and fabrication. The system will test the feasibility of the diffraction approach to the audio read-only memory, and serve as a model for the prototype reader development. Its features and characteristics are:

Patch size	150 × 150 μm
Data/patch	80 bits speech, 6 bits tracking
Speech sample rate	7200 samples/sec
Quantization	5 bits/sample
Speech/patch	2.2 msec
Patches/frame	50 × 50 = 2500
Speech/frame	5.5 sec

Fabrication of the breadboard LTS-2 audio recovery system is under way, and will be operating early in 1971. Although we can increase the recording density somewhat by using the present technique of two-level diffraction records, we expect to increase the density to 20 to 30 seconds per frame by developing analog record/read techniques.

1. Beam-Shaping Mask

Due to the Gaussian power distribution of a HeNe laser, excessive energy is incident on diffraction patches adjacent to the interrogated patch, shown in Fig. 4. Also, the convolution of the Gaussian beam and square film patch results in excessive crosstalk between data beams in the diffraction pattern. Therefore, efforts have been directed towards producing a mask which reduces energy on adjacent patches and reduces crosstalk in the data array.

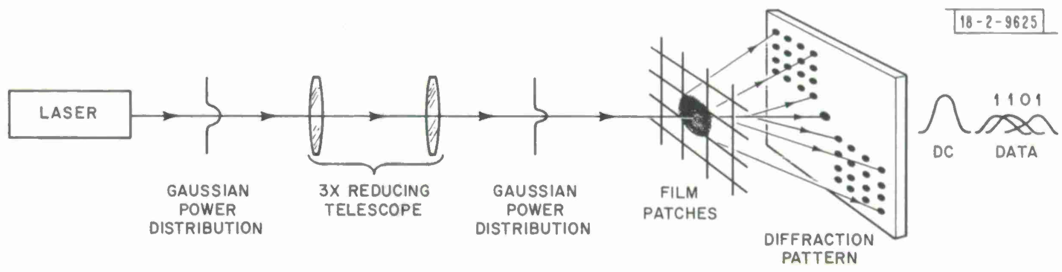


Fig. 4. System without laser beam truncation.

A square truncation clearly minimizes adjacent-patch illumination, but its SINC (x) Fourier transform has excessive crosstalk energy near the second zero, the location of adjacent data beams. Also the square truncation does not protect against beam-alignment error by having minimum energy at the edges of the patch.

We are now developing a window function to provide a desirable beam shape. We are using a film mask whose transmission is of the form $(1 + \cos bx)(1 + \cos by)/4$, with $b = 2\pi/450$, and with x, the horizontal component, and y, the vertical component, each in the range $\pm 225\,\mu$m. The shaped beam is later reduced in dimension by 3:1. These masks are being produced on the SC4060 computer, with samples of the desired transmission being coded using area modulation. The films are then photoreduced to the correct size. The function $(1 + \cos bx)(1 + \cos by)/4$ has a transmission distribution which allows for some laser beam misalignment and also has a transform with less energy in the region near adjacent data beams. Figure 5 shows pictorially the raised-cosine beam truncation and expected improvement in output-data crosstalk. Figure 6 shows measured intensity distributions for a laser beam truncated with a square aperture and with a raised-cosine mask, as observed in the plane of the data film. Figure 7 compares two complementary rows in a 10×10 data array with square and raised-cosine beam truncation. Further work will define the most efficient mask-production technique.

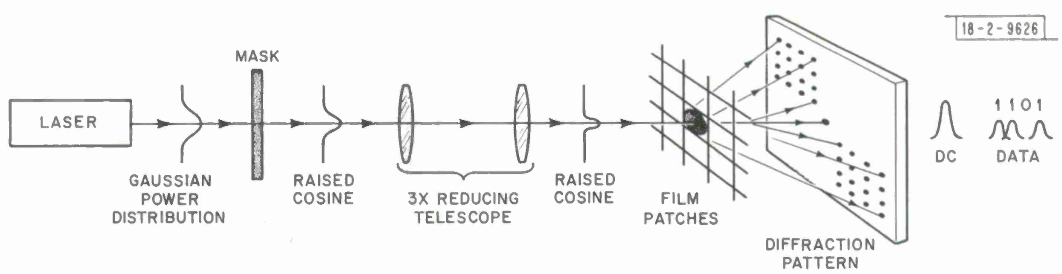


Fig. 5. System with raised-cosine beam truncation.

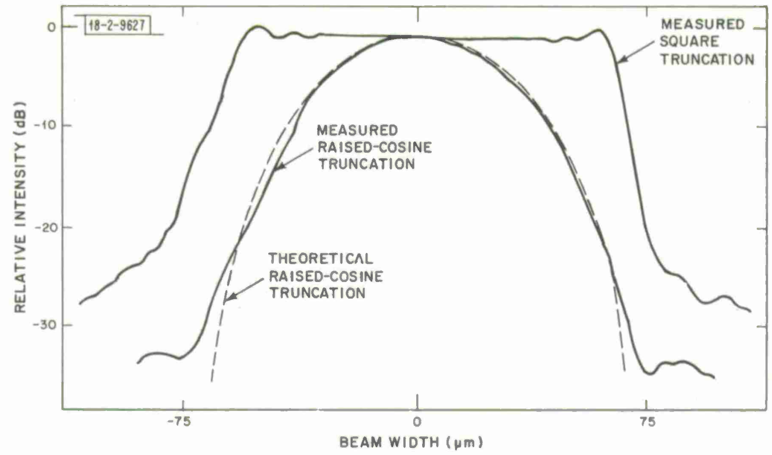


Fig. 6. Laser beam shape at the film plane.

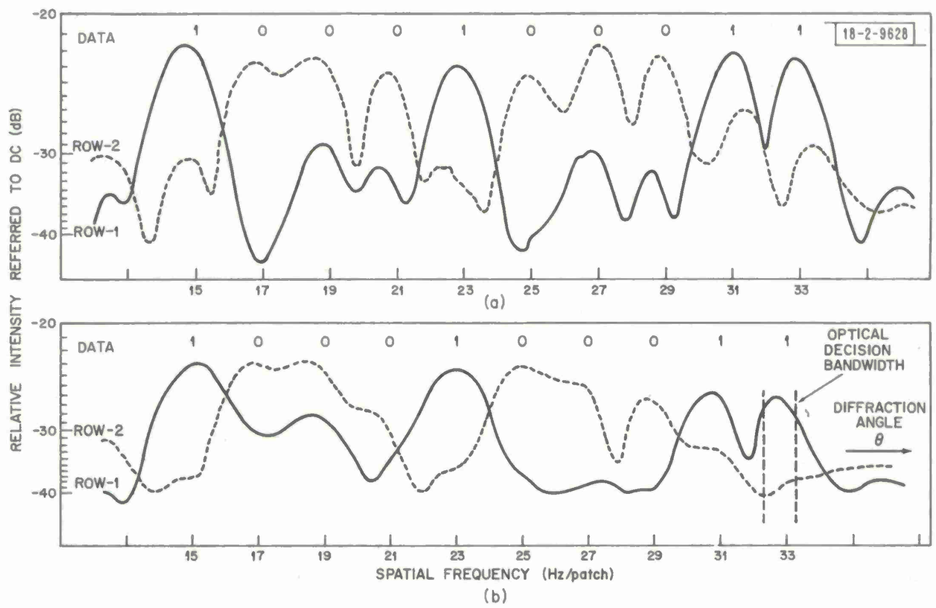


Fig. 7. Diffraction-pattern measurements: (a) square beam truncation; (b) raised-cosine beam truncation.

2. Laser Beam Deflection Devices

Effort continues towards the design and fabrication of laser beam x-y translation devices to permit the sequential interrogation of 150-μm-square diffraction patches, arranged in a 50 × 50 array.

A rotating prism with mechanical linearization correction has been selected as the horizontal translator. The prism must be polished to achieve surface tolerance of about 0.1 λ, and this limits the tolerance on the thickness of inexpensive prisms to approximately 25 μm. We require an "effective" thickness tolerance of 10 μm, and expect to achieve this by using an oversize prism (3X) followed by a 3X reducing telescope. These elements are shown schematically in the reader system block diagram Fig. 8. A prototype prism has been specified and is now being procured. A breadboard scanner employing a rotating cube has been produced. This scanner operates in

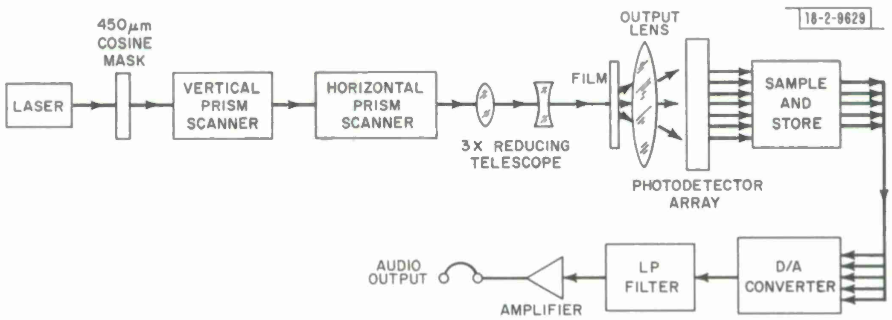


Fig. 8. LTS-2 breadboard system.

one axis only and is used in the evaluation of the audio patches. Since the rotating cube produces a nonlinear scan, the scanner incorporates a mechanical cyclic correction to linearize the scan. Using a computer program, it has been shown that the scanner is capable of linearity of ±0.1 percent. The computer investigation is continuing to ascertain whether or not some simple secondary correction can be applied to the device to improve scan linearity further.

3. Beam-Forming Optics

The beam-forming telescope forms a 3X reduced image of the aperture function. The two lenses are positioned so that the double Fourier transform of the aperture function is formed on the data film plane. Small adjustments are possible to compensate for the nonuniform phase front of the laser beam.

4. Output Imaging Optics

An output lens is used to focus beams diffracted by the data patch onto the photosensor array. The lens transforms angle to distance, and therefore focuses all beams diffracted at the same angle onto one photosensor. This is shown schematically in Fig. 9 (for simplification, a one-dimensional situation with the undiffracted beam (DC) and only one spatial frequency is shown).

5. Photodetector Array

Several techniques for the binary differential detection of pairs of data beams have been explored. Low data-beam power, estimated at 10^{-7} W, and the requirement for rapid readout due to the limited time in which the laser beam is reasonably well centered on a 150-μm patch,

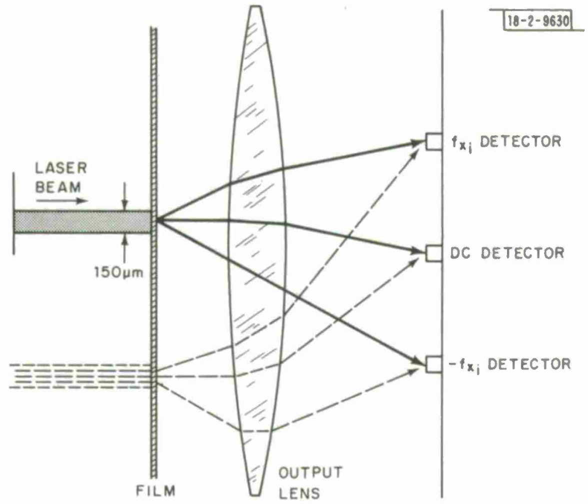


Fig. 9. Output lens imaging.

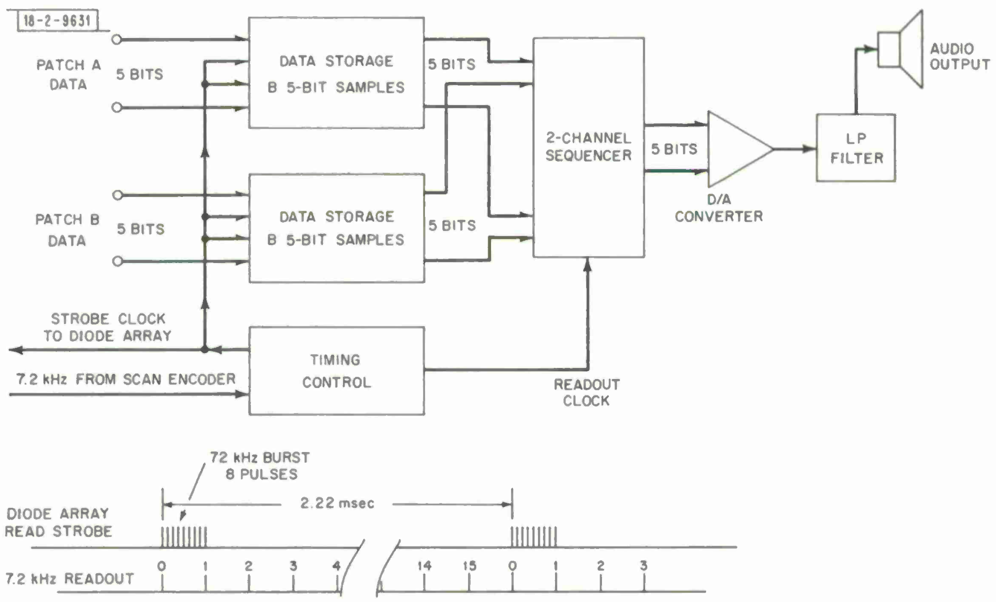


Fig. 10. Audio recovery logic block diagram.

imply a responsive, highly sensitive detector array. An in-house effort using high-sensitivity phototransistors [$1.5\,mA/(mW/cm^2)$] with collector bias gating for x-y selection in a 10×10 array is being designed and conceptually tested.

The Laboratory's Microelectronics Group is developing an IC photodetector array, and outside procurement has been initiated for two 10×10 photodiode arrays, with delivery expected by early January.

6. Strobe Electronics

The digital portion of the diode array strobe electronics, to be used in recovering the sampled audio, has been breadboarded and tested during the past quarter. A block diagram of the subsystem is shown in Fig. 10. Audio data, in digital form (sixteen 5-bit samples/patch) are strobed from patch pairs at a rate of 450 pairs/sec at a burst rate of 72 kHz. That is, the sixteen 5-bit samples (80 bits) are strobed into temporary storage within 111 μsec, every 2.2 msec. Between strobe bursts, the digital samples are converted to analog levels and sequentially outputted through a low pass filter at a rate of 7.2 kHz. Synchronization between array scanning, data acquisition, conversion and final readout will be electronically maintained by an optical rotoswitch, mounted on the shaft of the scan drive motor. The output of this rotoswitch will provide the 7.2 kHz system clock.

D. LTS-2 Digital Processor

The design of a digital processor to be used with the first LTS-2 system is essentially complete and construction is under way.

1. System Control

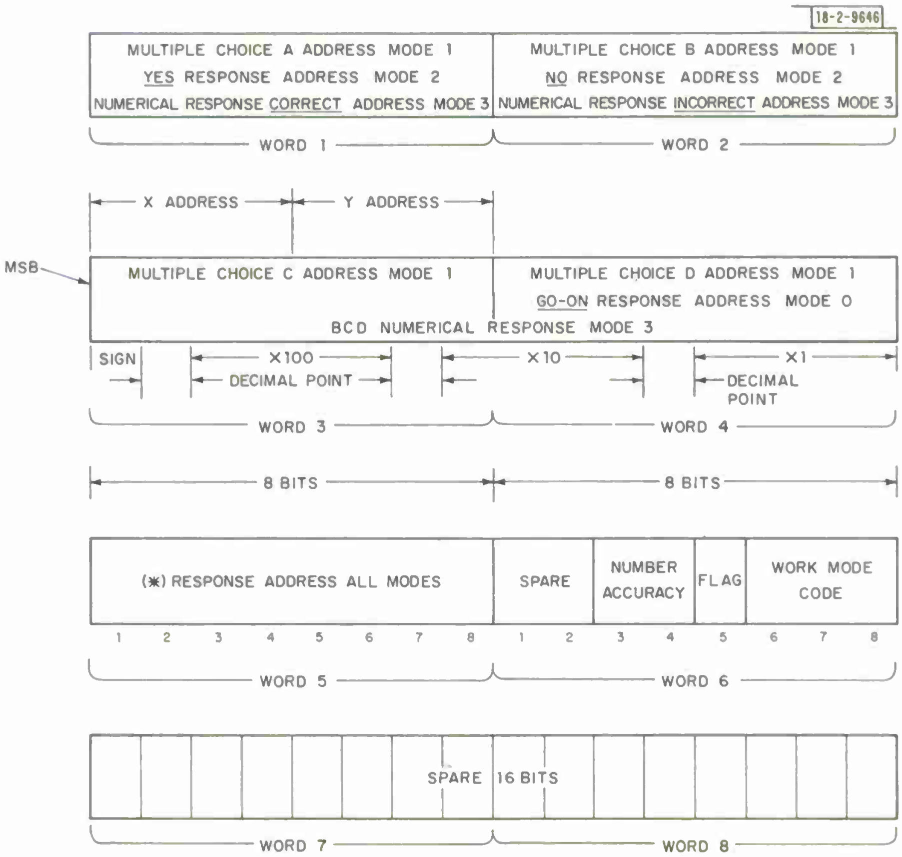
The LTS-1 system control is effected by student's keyboard responses to computer-program-controlled, visual and audible lesson material. The computer, in this case, holds both the frame-to-frame branching logic as well as the operating program that controls the hardware mechanics, such as changing slides, turning video or audio ON or OFF, etc. All computer actions are in response to keyboard inputs from the student. With LTS-2, the computer is replaced with a hard-wired digital processor and a microfiche digital storage medium. Frame-to-frame branching logic and other pertinent control information is photographically stored on microfiche cards while the system mechanics are controlled by the self-contained processor responding to the keyboard inputs, conditioned by the stored information.

2. Microfiche Cards

Lesson material for LTS-2 is carried on microfiche cards containing 192 frames each of visual material and an equal number of audio frames, forming a dual, 12×16 frame pattern. In addition to the material developed for screen projection, each video frame contains the above mentioned binary coded information used by the processor for controlling frame-to-frame branching logic. Control information is extracted from each frame photoelectrically as the frames are projected for viewing.

3. Keyboard

LTS-2 keyboard responses by the student are the same as those of LTS-1 with the following exceptions:



WORK MODE CODE

CODE	WORK MODE
0	GO-ON RESPONSE
1	MULTIPLE CHOICE RESPONSE
2	YES or NO RESPONSE
3	NUMERICAL ANSWER RESPONSE
4 THROUGH 7	UNASSIGNED

ACCURACY CODE

CODE	ACCURACY (decimal places)
0	3
1	2
2	1

Fig. 11. LTS-2 microfiche frame control block format.

(a) The "Special" key is replaced with a "Forth" key to give a BACK/FORTH key pair for scanning operations.

(b) Minus sign and decimal point keys are added to the numeric side of the board.

(c) The E and F (multiple choice) keys are deleted.

As with LTS-1, the keyboard contains an error light to indicate keypush errors. When the indicator is lighted, all keyboard inputs are inhibited, except the CLEAR key. The CLEAR key extinguishes the light and re-enables the keyboard. The keyboard also contains a mode light which is on whenever the student is in scan mode operation.

4. Operating Modes

As described in a previous report,* there are two modes of student operation, scanning and working. Scanning generally involves a search for a place to start work. This can take the form of going back and forth over previously worked frames or selecting particular frames through the use of the index frame. All frames have x-y fiche coordinate numbers, by which they may be selected from the keyboard. To select a particular frame, the student simply enters the x-y number of the frame at the keyboard and presses the SELECT key. "Working" means to progress through frames in a manner prescribed by the author. There are four different types of response for which the author may program his lesson material. He may require the student to respond with a simple GO-ON keypush, or a frame may call for a multiple choice response, a YES or NO answer or possibly a numerical response. For each acceptable keyboard response to a frame of material, there is an associated branching address stored on the microfiche. The numerical response requires 16 bits to accommodate the three-digit, BCD, signed number allowed the student and, in addition, two 8-bit x-y addresses to account for either correct or incorrect answers. All other responses require a single 8-bit x-y frame address. The number of bits required to cover branching for all possible responses is 96, or twelve 8-bit words. By means of a simple mode code, the 12 words are submultiplexed into five 8-bit words as shown in the control block format Fig. 11. Allowing for a control word of 8 bits, two spare words for author's coding and additional choice option, the control block data in each microfiche frame requires 64 bits. The work mode code, carried by bits 6, 7 and 8 of word 6, is listed in Fig. 11.

5. Numerical Entry

As mentioned above, the LTS-2 system allows the student to make numerical responses from the keyboard of up to three digits with sign and decimal point. Any such entry is terminated by a GO-ON keypush, after all audio, associated with the frame is complete. That is, (GO-ON – audio end) causes the numerical entry to be accepted by the processor where it is compared with the number coded in the control block of the fiche frame. If the numbers compare, the microfiche positioning system is directed to the address designated by word 1 of the control block. If no comparison, word 2 is the directing address. In some cases, the author may wish to relax the accuracy requirements for particular mode 3 frames. Bits 3 and 4 of word 6 control this parameter. If both bits are zero, the number comparison and right/wrong decision is based on all three digits. Binary 1 calls for a comparison of only the two high-order digits and binary 2 compares only one place of the three-digit response.

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* Educational Technology Program Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 September 1970), pp. 1-2.

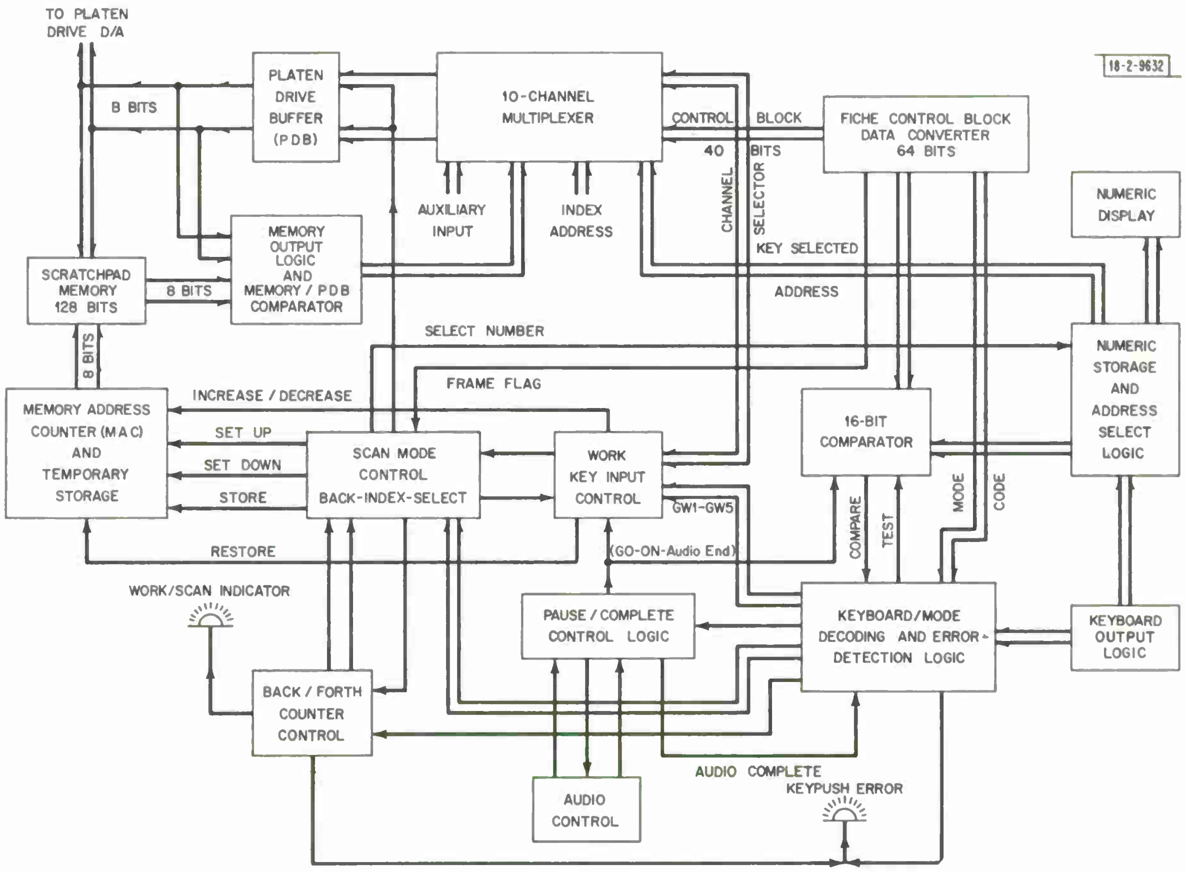

Fig. 12. LTS-2 processor block diagram.

6. Frame Address Storage

A flag, bit 5 of word 6 in the control block of each frame, acts as an indicator to the processor, as to which frames, when encountered during a lesson, are to be stored for go-back (scan) modes of operation. A "one" in bit 5 is taken as the flag; the addresses of such frames are stored in a 16-word scratch-pad memory included in the processor. The stored history of flagged frames is consequently limited to sixteen, after which the oldest is written over by the most recent.

7. Pause/Complete

Response to pause signals in the audio portion of a frame is the same as for LTS-1. A GO-ON keypush causes the audio to continue, if in a pause state, or to step to the next frame, if completed, and GO-ON is a proper response (that is, if the frame is a mode 0 frame). LTS-2 includes an additional feature to allow override of the audio. One push of the GO-ON key, while audio is playing, is stored and takes effect at the audio pause or end, whichever comes first. Two pushes of the GO-ON key, however, overrides the audio and causes a GO-ON to the next frame without waiting for the audio-end signal.

8. Control Block Coding

The processor responds to keyboard inputs, conditioned by the coded information stored on the microfiche frame. As an example of control block coding, assume the author uses a frame of material for which he requires a YES or NO response from the student. He codes the control block of that frame as follows: the mode code in word 6 of the block is coded binary 2 for a YES or NO response; that is, bit 7 is a "one." If the author wishes the frame to be stored, as part of a scanback chain, he makes the flag, bit 5 of word 6, a "one," also. All other bits of word 6 are zeros. Referring to Fig. 11, word 1 is coded with the x-y address of the frame that the author wishes to be presented if the student responds with a YES keypush and, as indicated in the figure, the address coded in word 2 for this mode is the NO response branching address. The author would probably give the student the option of pressing the asterisk (*) key if a YES or NO answer was not obvious to him. The asterisk key branching address, word 5 of the control block, is available for use in all modes. For this particular frame, the mode code 2 enables gates in the processor where a YES or NO keypush transfers either the word 1 or word 2 address, depending on which key is pressed, through a multiplexer to an x-y platen positioning system. An asterisk (*) keypush transfers the address of word 5 to the x-y drive. Any keypush other than a YES, NO or asterisk (*), in this case, lights a keypush error light on the keyboard. A block diagram of the LTS-2 processor is shown in Fig. 12. The work mode, coded in word 6 of the microfiche frame, conditions the processor, through gating, as to which keyboard inputs are acceptable for that mode. An unacceptable entry lights the error light. The above example was for mode 2, which allowed only a YES, NO or asterisk (*) response. This holds true for all modes listed at the bottom of Fig. 11.

9. Scan Mode Operation

Keyboard inputs, used in a scan type of operation, are not affected in any way by the control block data stored on the microfiche. The student may enter the scan mode at any time, in a number of ways, such as selecting the index frame, by simply pressing the INDEX key or

selecting any other frame by entering its number and pressing SELECT; or he may wish to retrace his lesson steps by pressing the BACK key. The FORTH key is also used in scan operations, but for obvious reasons must be preceded by at least one BACK action. Upon entering a scan operation, an indicator is lighted on the keyboard to remind the student that he is in a scan mode and frames covered in such, are not stored for later scanback. A working response to any frame, while in the scan mode, immediately returns the processor to work mode conditions, extinguishes the SCAN indicator and once again falls under partial control of the microfiche data block.

E. Related Component Research

Another method is being developed to retrieve data from each audio patch on the microfiche using a fiber-optics scanning technique.

This consists of two 10×10 arrays of fibers that are illuminated by the diffracted laser beam. The fibers are routed in pairs to a circular array, which is scanned using a rotating disk. Each pair of fibers is scanned by two phototransistors mounted on the disk to collect one bit of audio information. This is fed to a differential, binary detector circuit and through slip rings to an amplifier.

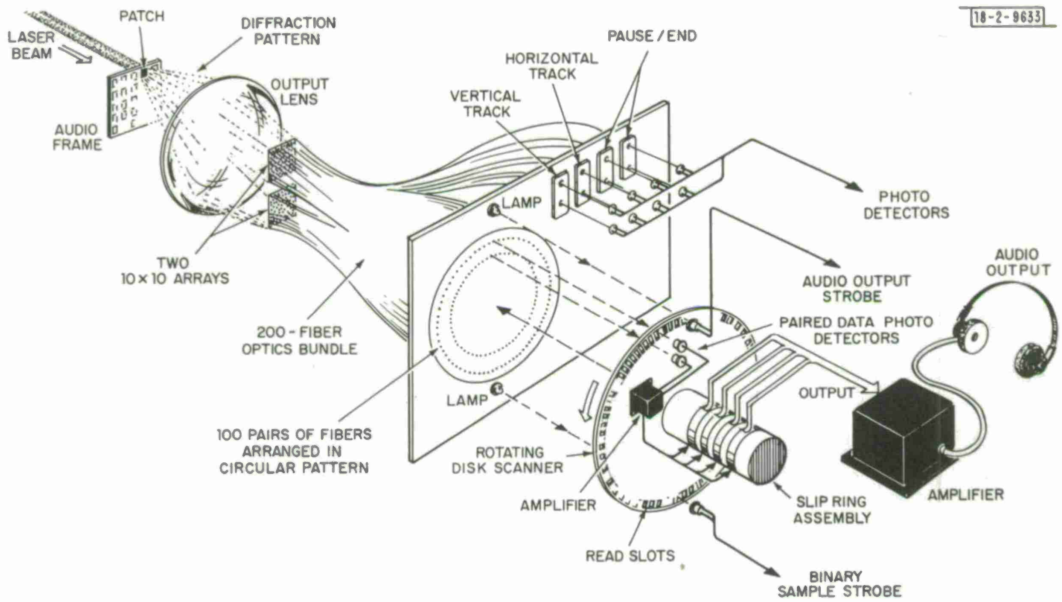

Fig. 13. Fiber-optics output array.

Output strobe and read information can also be derived by using separate light sources and detectors and appropriate slots on the rotating disk. Other pairs of fibers are to be brought out directly to provide horizontal track, vertical track, and audio pause/end signals. A schematic diagram showing the use of a fiber-optics array is shown in Fig. 13.

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13. ABSTRACT

Work this quarter has concentrated on planning for the Keesler trial of the LTS and the design of appropriate facilities to support that effort. Considerable progress has been made in the hardware development program. In particular, techniques have been developed for storing, on microfiche, sampled audio signals as two-level diffraction gratings. Construction of the LTS-2 breadboard system has begun.

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